

# Small Wind Power for Homes, Farms, and Businesses



Jim Green, NREL

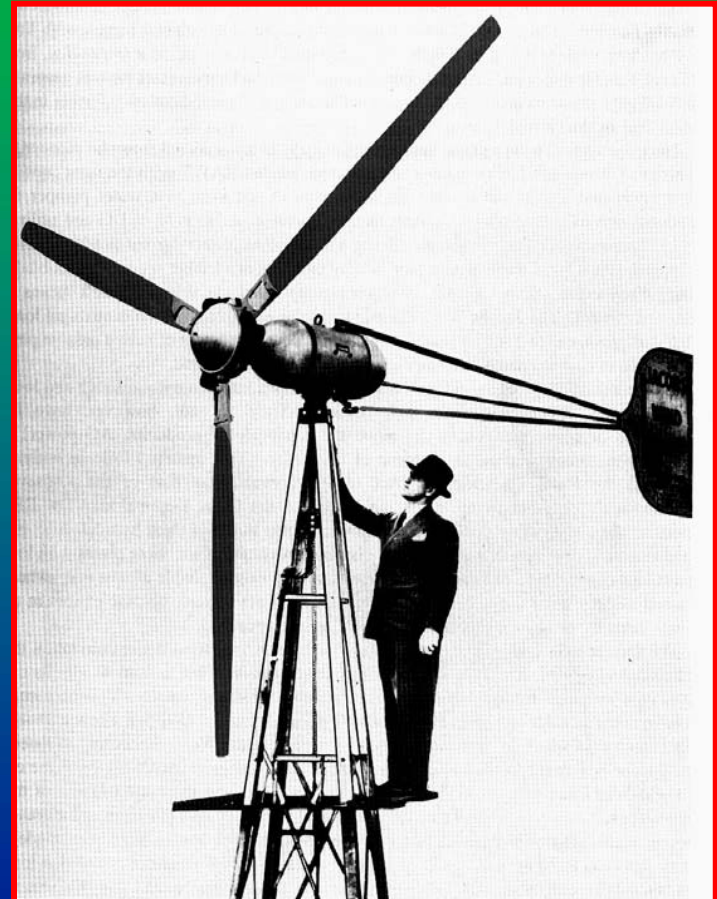
Colorado Wind and Distributed Energy Workshop  
April 8-9, 2002

# Wind Energy History in Rural America



Water-pumping wind mills,  
from about 1860

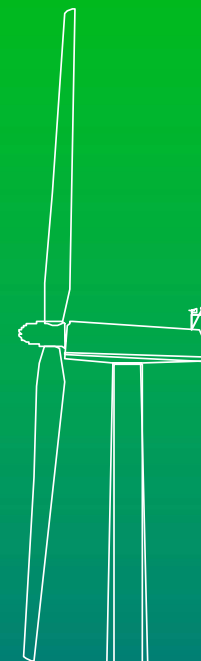
“Wind-chargers” for electric power,  
during the 30’s and 40’s



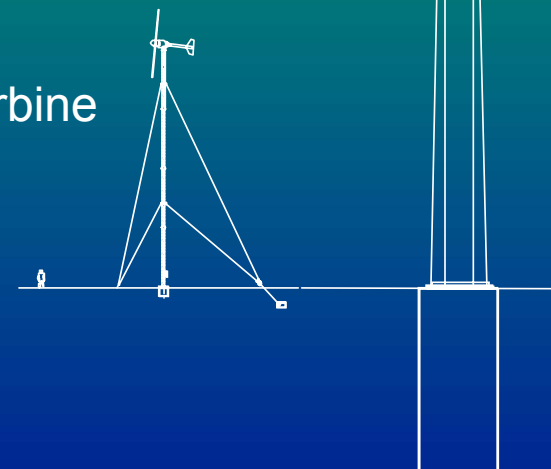
# Small Wind Turbines are Different

- Large Turbines (600-1800 kW)
  - Installed in Windfarms, 10 - 100 MW
  - Provide Low Cost Power to the Grid
  - < \$1,000/kW
  - Require 6 m/s (13 mph) Average Wind Speeds
- Small Turbines (0.3-50 kW)
  - Installed Off-Grid or at On-Grid Facilities
  - \$2,000-6,000/kW
  - Designed for Reliability / Low Maintenance
  - Require 4 m/s (9 mph) Average

1,500 kW  
Wind Turbine



10 kW  
Wind Turbine



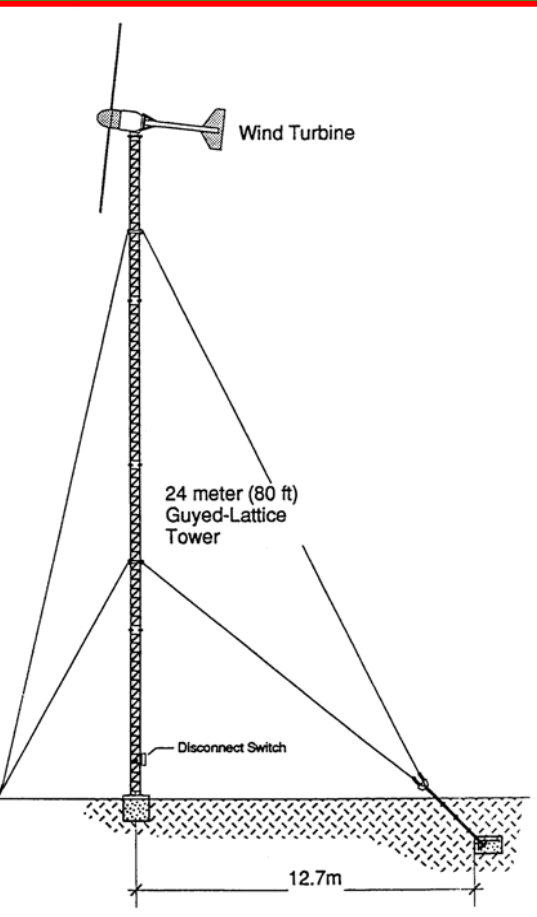
# Small Wind Turbines

- **Configuration:** 2 or 3 blades, aimed into the wind by the tail
- **Blades:** Fiber-reinforced plastics
- **Over-speed Protection:** Furling (rotor turns out of the wind), no brakes
- **Generator:** Direct-drive, permanent magnet alternator (no brushes), 3-phase AC, variable-speed operation
- **Controller:** Electronic device that delivers
  - DC power for battery-charging
  - AC power for utility connection
- **Result:**
  - Simple, rugged design
  - Only 2–4 moving parts
  - Little regular maintenance required

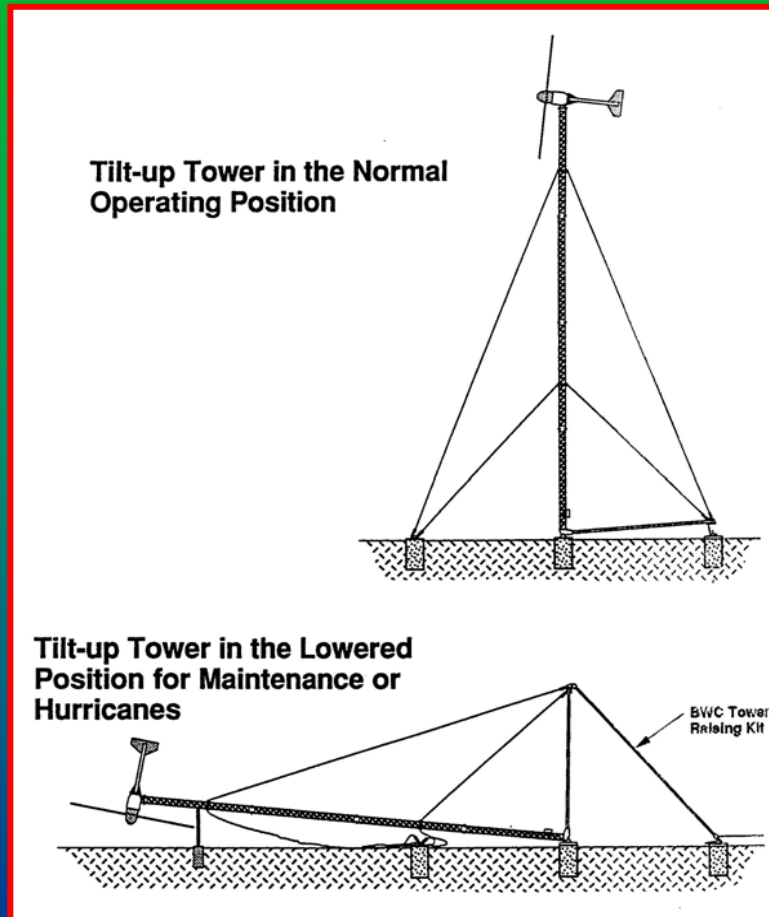


Bergey EXCEL, 10 kW

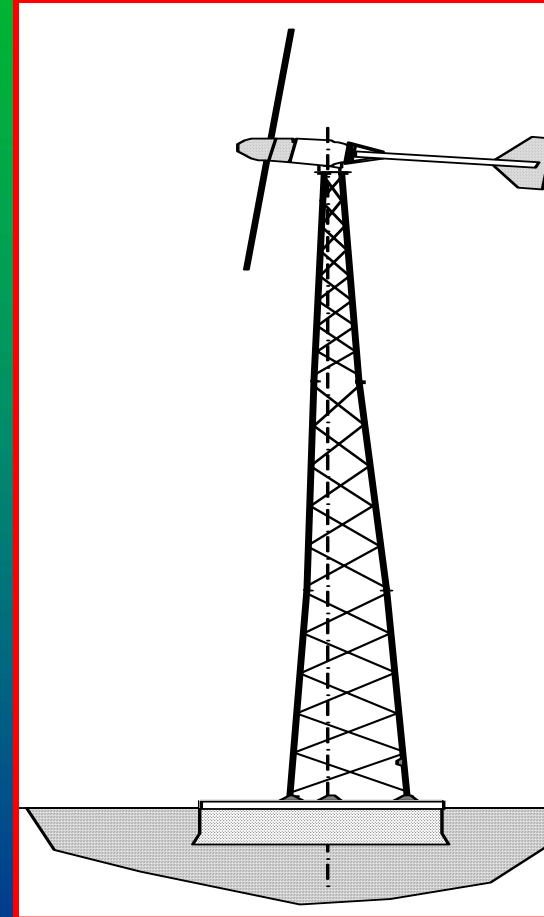
# Small Wind Turbine Towers



**Guyed Tower**



**Tilt-Up Tower**



**Self-Supporting  
Tower**

# Small Wind Turbine Maintenance and Lifetime

- “Low maintenance” not “no maintenance”
  - Inspection and maintenance every 1-2 years
  - Inspect mechanical and electrical connections, check for corrosion, check guy wire tension, inspect/replace leading-edge tape, etc..
  - Beyond 10 years: blade or bearing replacement may be needed
- Lifetimes of 10 to 30 years are expected with proper installation and annual maintenance
  - “A wind turbine will see as many operating hours in one year as an automobile will see in 200,000 miles!”*

# Small Wind Turbine Cost & Warranties

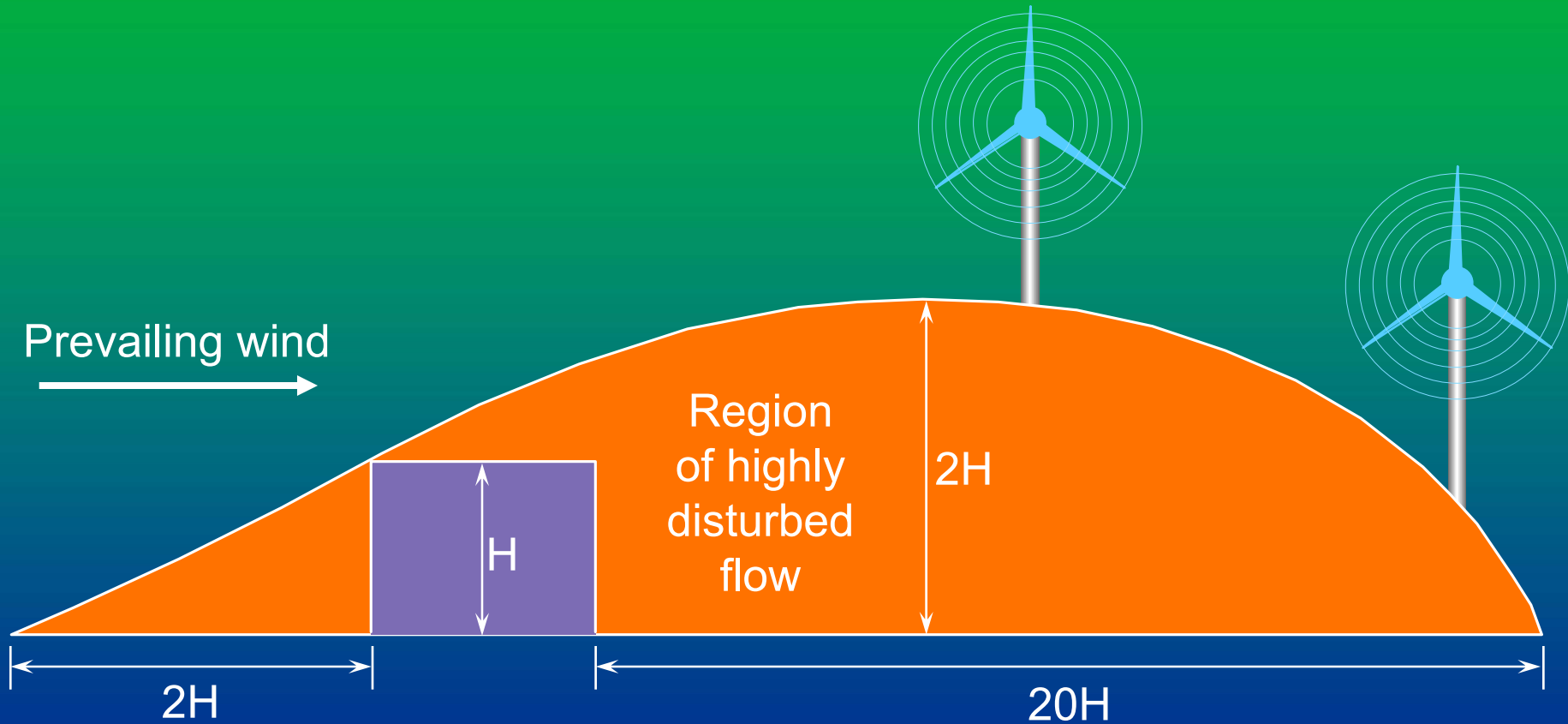
- Initial cost is between \$2,000 and \$6,000/kW for a small wind turbine, controller, and tower
- There is a trade-off between the incremental cost of a taller tower and increased energy output
- Buyers must make judgments between initial cost and rugged/durable design.
- Warranties
  - 2-5 years
  - Coverage of “materials and workmanship”

# Zoning for Your Wind Turbine

- Short towers, 30–35 ft, can be installed with only a building permit (permitted use, accessory use)
- Taller towers often require a “special use review” by the county commissioners
- Zoning issues include:  
property size, setbacks, tower height, noise, obstruction of views, compliance with safety standards, etc.
- Zoning approval may be difficult or impossible to get for urban and suburban locations, is less a problem in rural locations



# Micro-Siting Example: Obstruction of the Wind by a Building



# Southwest Windpower

Flagstaff, AZ



AIR-X  
300 W



Whisper  
H40  
900 W



Whisper  
175  
3 kW



503  
500 W



Whisper H80  
1000 W

# Bergey Windpower

Norman, OK



# Wind Turbine Industries, Inc.

Prior Lake, MN

Jacobs  
29/20  
20 kW



# Atlantic Orient Corp.

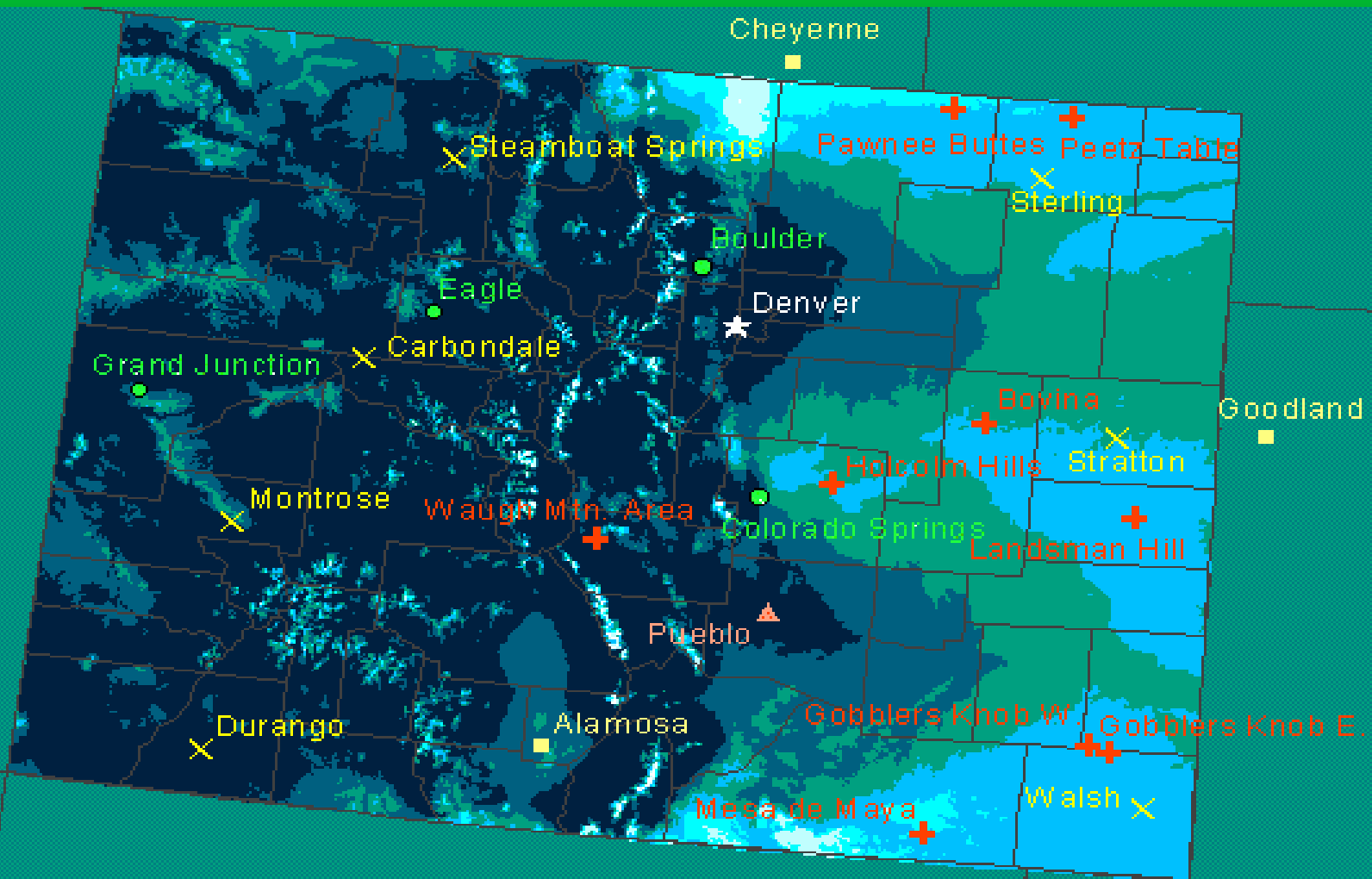
Norwich, VT

AOC 15/50  
50 kW



# Colorado Wind Resource Map

<http://www.coloradoenergy.org/corrd>



Anemometer height: 10 m		
	Max. wind power density (W/m <sup>2</sup> )	Max. wind speed (m/s)
	100	4.4
	150	5.1
	200	5.6
	250	6.0
	300	6.4
	400	7.0
	1000	9.4

	WEST Associates - Hourly solar, wind and temperature
	WEST Associates and NSRDB - Hourly solar, wind and temperature
	JCEM and NSRDB - Hourly solar, wind and temperature
	NSRDB - Hourly, monthly, and TMY2 solar, wind and temperature
	Public Service Co. - Annual average wind speed
	JCEM - hourly solar, wind and temperature

Source: Office of Energy Conservation  
Utility Wind Resource Assessment (1995)



# Case Study: On-Grid Farm with Wind System

- Southwestern Kansas
- Utility bill reduction
- Bergey Windpower Excel wind turbine  
10 kW, 23 ft rotor, 100 ft tower
- ~21,000 kWh/year generation,  
utility bill savings ~\$2,800/year
- Installed in early 1980s, ~\$20,000,  
received federal tax credit
- Maintenance costs \$50/year
- One lightning strike, damage was  
covered by farm insurance



# Case Study: On-Grid Small Business with Wind System

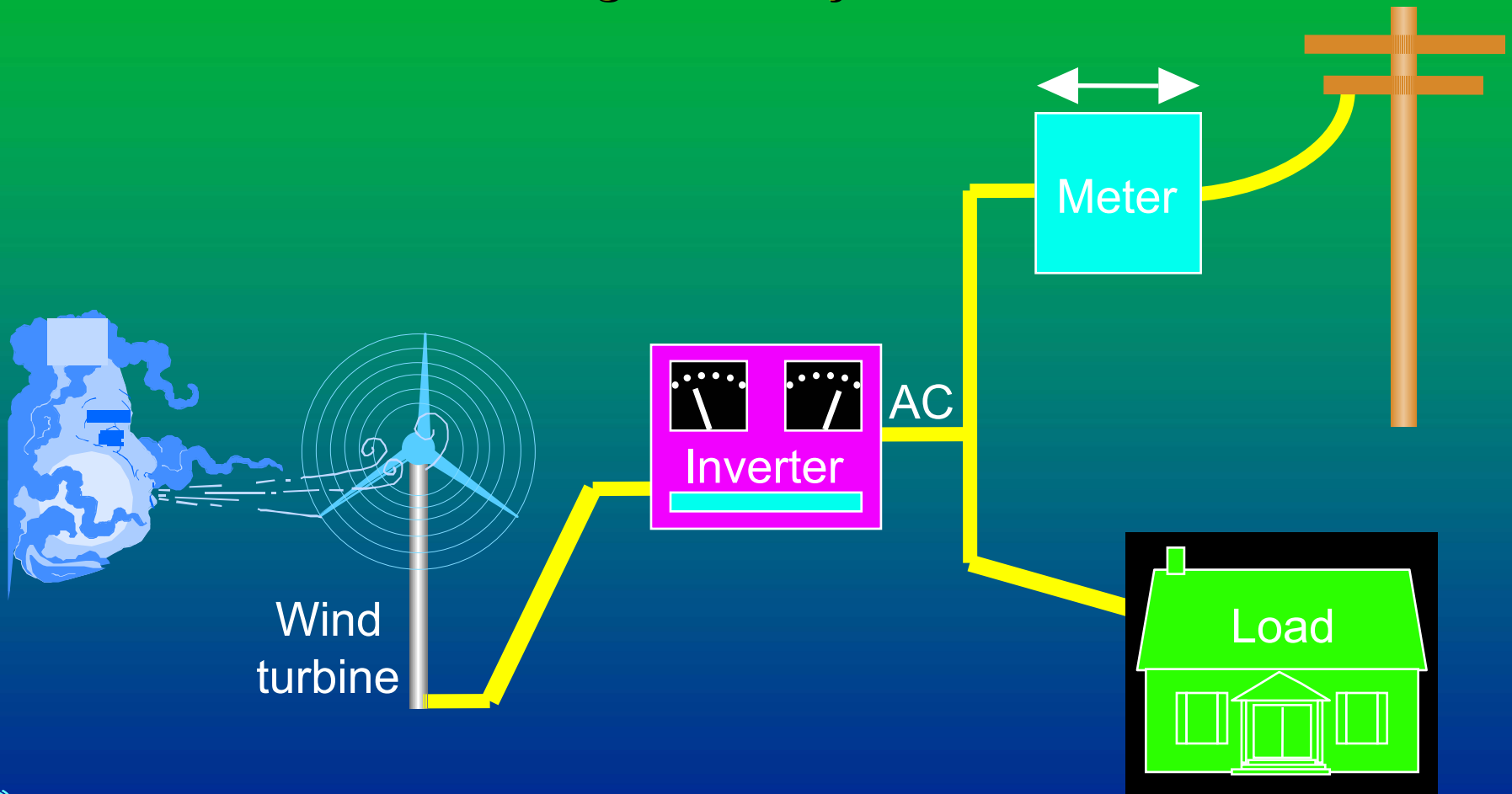
- R&M Mechanical Systems, Norman, OK
- Net-metering for utility bill reduction
- Bergey Windpower Excel wind turbine, 10 kW, 23 ft rotor, 80 ft tower
- ~15,000 kWh/year generation, utility bill savings are ~\$1,300/year
- Installed in 1984, ~ \$22,000
- Owner received an \$8,000 tax credit and 5-year depreciation
- Maintenance and repair costs ~\$75/year





# On-Grid Wind System

## Net Metering for Utility Bill Reduction

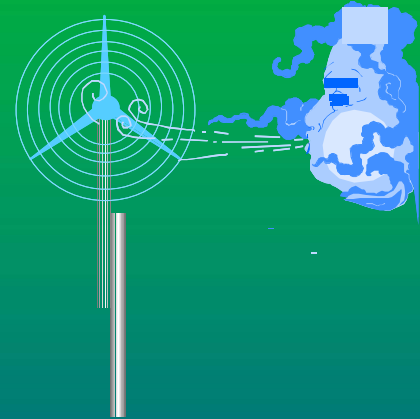


# Net Metering of Renewable Energy

Energy  
consumed  
immediately:  
retail rate

Excess energy used to  
**offset** consumption at  
another time: retail rate

Net excess energy (determined  
monthly or annually): retail rate,  
avoided cost, or given to the utility



# Case Study:

## On-Grid Factory with Wind System

- G.M. Allen & Sons, Orland, ME, blueberry processing plant
- Net-metering for utility bill reduction
- Atlantic Orient 15/50 wind turbine, 50 kW, 49 ft rotor, 100 ft tower
- Installed in 2001, ~ \$150,000

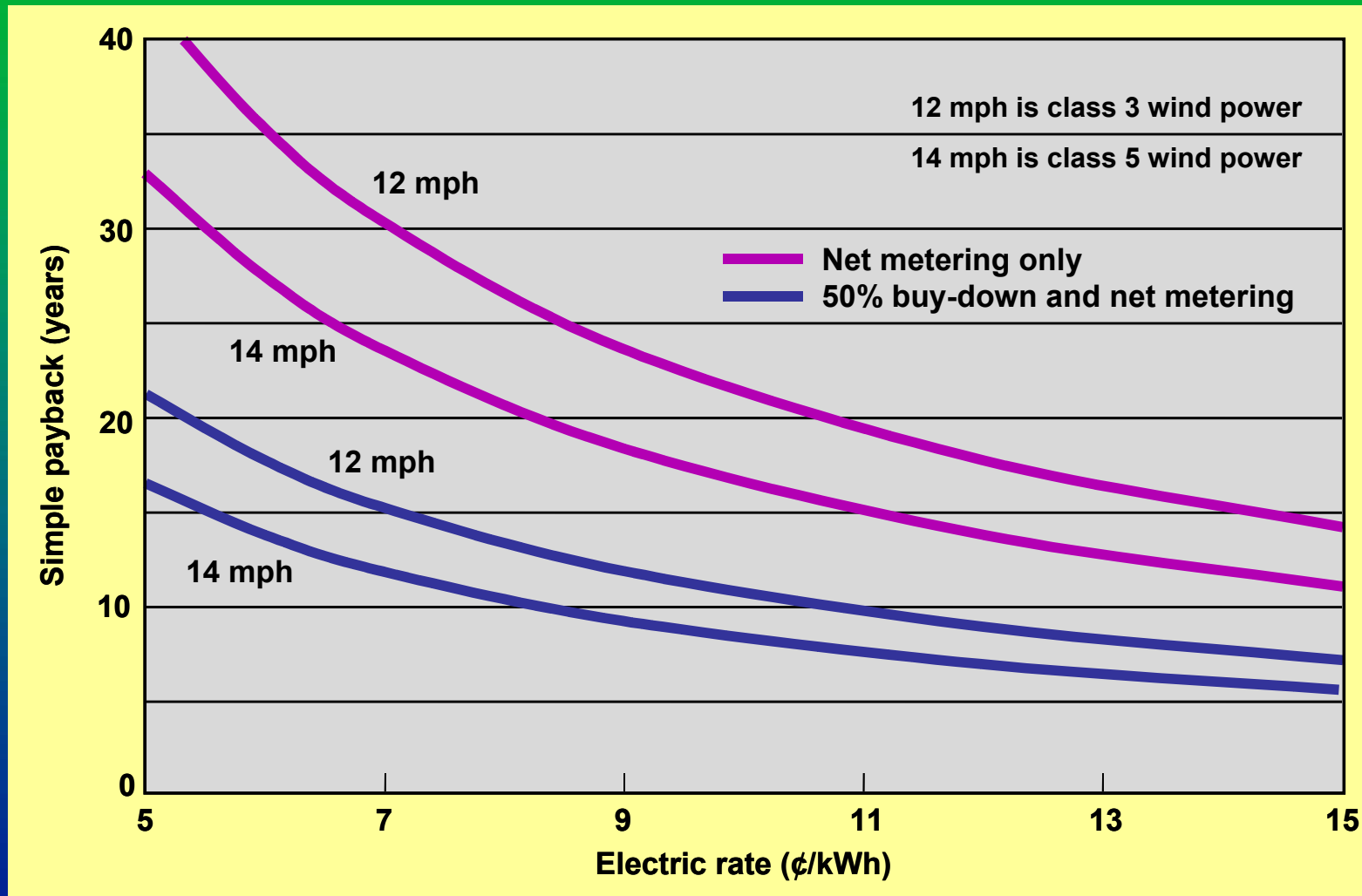


# Case Study: On-Grid Home with Wind System

- Tehachapi, CA, net metering for utility bill reduction
- Bergey Excel wind turbine, 23 ft rotor, 10 kW
- Total installed cost was \$34,122 in October 1999
- California Buy-Down Program, \$16,871 cash rebate
- Estimated payback: 6 years



# Incentives Make Small Wind Systems More Economical



# Will Wind Energy Work for Me?

- Good wind resource?
- One-half acre or more of land?
- Local zoning rules/process or neighborhood covenants that allow wind turbines on at least 60–80 ft towers?
- Farther than 1/4 mile to utility distribution lines?
- Comfortable with long term investments?
- Concerned about future electricity prices?
- Concerned about the environmental impacts of electric power generation?
- A desire to be more self-sufficient or completely independent of the electric utility?

# Case Study:

## Off-Grid Home with Wind/PV System

- West of Boulder, CO, at 9,000 ft
- Bergey 1500 wind turbine, 1.5 kW, 70 ft tower
- Solarex PV panels, 480 W
- 24 VDC battery, 375 Ah
- Onan generator, propane-fueled, 3 kW (at altitude)
- Trace inverter, 120 VAC, 1 phase
- Propane used for range, refrigeration, space heat, hot water (w/solar pre-heat)
- First wind turbine installed in 1978, fourth wind turbine now in service
- PV installed 1984 w/ tax credits
- System cost about \$20,000



# Case Study:

## Off-Grid Cabin with Wind/PV System

- South Park, Colorado at 9660 ft elevation
- Southwest Windpower 503 wind turbine, 500 W, 5 ft rotor, 32 ft tower
- PV panels, 188 W
- 24 V DC battery bank
- Heart inverter, 2.5 kW, 120 VAC
- Space heat from wood & propane
- Propane used for hot water, range, and refrigerator
- Off-grid cabin occupied 2–3 weekends/month
- Installed 1986–1992, ~\$7500
- Today's cost ~ \$5,000





# Costs for Line Extensions



Source: PG&E



# Off-Grid Wind Water-Pumping

- Ranch near Wheeler, TX
- Water-pumping for 120 head of cattle
- Whisper 1000 wind turbine, 1 kW, 9 ft rotor, 30 ft tower

# Case Study: Off-Grid Stock Tank Pumping and Heating

- University of Wyoming
- Bergey Windpower 1500 wind turbine, 1500 W, 10 ft rotor



# Questions?

